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ABSTRACT

Although an increasing number of theoretical analyses and evaluations have been conducted since microcomputer technology was developed and introduced into classrooms, few new studies have been undertaken on the costs of these new information technologies (NIT). This report focuses on the methodological problems that must be solved in order to assess the costs of NIT and on possible consequences of the use of NIT on the cost of education. The first section addresses some general principles of cost analysis of educational systems using NIT, including discussions of basic concepts used in cost analysis and differences in cost structures between conventional education and a system making extensive use of NIT. The second section considers the effects of an extensive introduction of NIT on the costs of conventional education in both developing and developed nations, including costs of equipment, hardware operation, and other operations. Probable cost implications for the use of NIT in distance teaching are outlined in the final section. (GL)

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CHARACTERISTICS AND PROBLEMS OF MEASUREMENT

by

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Costs of the New Information Technologies

in Education :

Characteristics and Problems of Measurement

Education systems as we know them today are costly. Not only does their operations consume a sizeble part of the total ressource of the community (3 to 10 per cent of the GNP, according to the country) and a large part of the national budget (generally between a fifth and a third), but their unit cost is showing a rising tendency. They are increasingly being accused of inefficiency and inability to adapt to the new demands made on them. As a result, all countries are considering reforms that could bring about a better ajustment between supply and demand, as well as meeting the needs at a supportable cost, bearing in mind that resources have reached their maximum and, in some cases, are sometimes on the decline.

Despite the semi-failure of the new audio-visual teaching methods introduced during the last two decades, made hope in placed at present on an extensive use of the New information Technologies (NIT). Particularly on account the potential interaction of the medium and its simulation capacity, improved teaching efficiency is expected. Ardent supporters of the micro-computer and its peripherals also argue that an intelligent use of such equipment could appreciably reduce teaching costs.

An increasing number of theoretical analyses and evaluations have been made since micro-computer technology was developed in 1974 and introduced for the first time into classrooms towards the end of the 1970s. A reading of these reports unfortunately reveals that even though we are increasingly well informed about the efficiency of the micro-computer (especially its use in the acquisition of cognitive knowledge), few new studies have been undertaken on the costs involved, and those that have appeared do not fill in the gaps and inadequacies of the information available two years ago.

Moreover, the research techniques have not yet been standardized and remain unsatisfactory. That is why, instead of updating the data already presented (1), I shoud prefer to focus this report on the methodological problems which must be solved if our information is to be improved, and on the possible consequences of the use of the NIT on the cost of education.

The cost analysis of a traditional education system, and of a system making massive use of NIT, cannot be conducted in the same way.

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(1) Cf. my report : "Aspects économiques de l'introduction des nouvelles technologies de l'information dans l'éducation". To the Conference on Education and the News Informations Technologies, DECD, July 1984, 51 p.

The introduction of NIT into education not only involves the cost in the overail cost structure and its variation patterns in turns of the size of the system. This change is more profound when the new technologies are set up outside the conventional school rather than being used by the scool itself. Accordingly, we shall begin by looking at the general cost structure, and an appropriate method for its analysis, and then go on to analyse the consequences of the introduction of NIT on the costs of conventional education, before studying the cost structure of out-of-school training.

I. General principles of cost analysis of education systems using NIT.

A brief recapitulation of the logic and categories underlying cost analysis is indispensable to proper clarity as regards, the differences in the cost structure and variation patterns between the conventional education system and a system using NIT, and in respect of the problems the financial data normally available pose for the economist.

(A) Logic and categories of cost analysis

The main problem in any cost analysis is that of optimization. This means that it never examines the costs (sacrifices) for their own sake, but studies their bearing on the benefits, yielded by the actions that bring about these costs. This also means that the analysis is not interested in the total cost of an operation or of an object in itself, but in its strucutre and the way it varies with the level of production.

The essential distinction from the economist's point of view is the distinction between total cost and unit cost.

It is indeed important to know wether the cost per unit produced increases, decreases or remains stable when production increases, in order to determine at what level the unit cost is the lowest. This, in turn, raises the question of the choice of a reference unit.

In the case of an ordinary commercial product, this choice does not give rise to any problem : the unit of reference is the unit of the product marketed. But in the case of education, this is less obvious. The answer to the question of what the education system produces is many-sided - the system imparts knowledge and creates new knowledge, produces "socialization" and so forth - and controversial. Even if it agreed, for the sake of argument, that the transmission of knowledge is the main "product", this "product" is not easy to measure directly. The assumption is generally made that the volume of knowledge transmitted during a given period of time is always about the same, and that the pupil can be taken as the unit of measure. This itself is based on two assumptions which - especially the second - may falsify comparison between the conventional system and the system making use of NIT.

The first assumption is that the "quality" of teaching and of pupils is homogeneous, so that the same curriculum is transmitted and assimilated in the same way in all the classes. While this is already problematic when comparisons are attempted within a given system (2), it is quite unrialable when two different systems are being compared.

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(2) For example, if it can be demonstrated that the teachers with the highest qualifications are the best, that is to say that they teach more to their students, the fact that they cost more should not be taken into account without reference to their quotas efficiency.

In particular, if it can be demonstrated that a system making massive use of NIT transmits, on average much more knowledge. Then , the conventional system (3), the fact that its cost per pupil may be higher cannot in itself be taken as a criterion in choosing between the two systems. the second assumption is that the rate of transmission of knowledge is fixed by the curricula, which are themselves imposed uniformly on all schools. Yet, if the reaching method using NIT is capable of transmitting the same amount of knowledge more rapidly, it is possible to reduce the duration of each course. In that case, it is no longer the cost per pupil over a period of time (normally a year) that is the revelant variable, but the cost per pupil completing the course or graduating.

This is accordingly a first example of a problem that can arise when two very different systems are compared with the help of indices developed for the evaluation of one of them.

The necessity of observing precisely how the cost varies in relation to the volume of production leads the economist to use another category differentiating between average cost and marginal cost.

Average cost is unit cost. For a better understanding of its evolution when the level of production changes, it is necessary to compare it with the marginal cost, that is to say the variation of total cost when the quantity produced changes by one unit. The relation between average cost and marginal cost can be more readily understood if total cost is broken down into two parts : fixed costs and variable costs. A cost is said to be fixed when it does not vary with the level of production. Such a cost is incurred once and for all. That is the case for example with the cost of building a factory or a school. A variable cost, on the other hand, is one that increases with the level of activity, for example, the cost of raw materials or of energy. It does not necessarily vary in parralel with productive activity, but it varies in the same direction.

Average cost is comprised of fixed costs and variable costs. It tends to decrease as production increases, at least to a certain degree, if fixed costs are substantial, since these are distributed over an increasingly large number of units.

The marginal cost, on the other hand, includes only variable costs, since the fixed costs are incurred right from the start and do not vary with a change in the volume of production. If the fixed costs are substantial, the marginal cost is much less than the average cost when the level of production is low. it can be said that there are economies of scale, as we can produce at a lower cost by producing more.

The use of these intruments of cost analysis enables us to understand better the difference in cost structure between the conventional education system and the education system with massive recourse to NIT.

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(3) Wether it be because courses prepared by highly qualified specialists are better, or because the pupils are more stimulated by this method of teaching and therefore work harder, or because a differentiated method of teaching enables each student to learn at his own pace and minimizes loss of time, or for some reason.

This advantages obviously do not exclude possible differences in other areas, especially the emotional aspect.

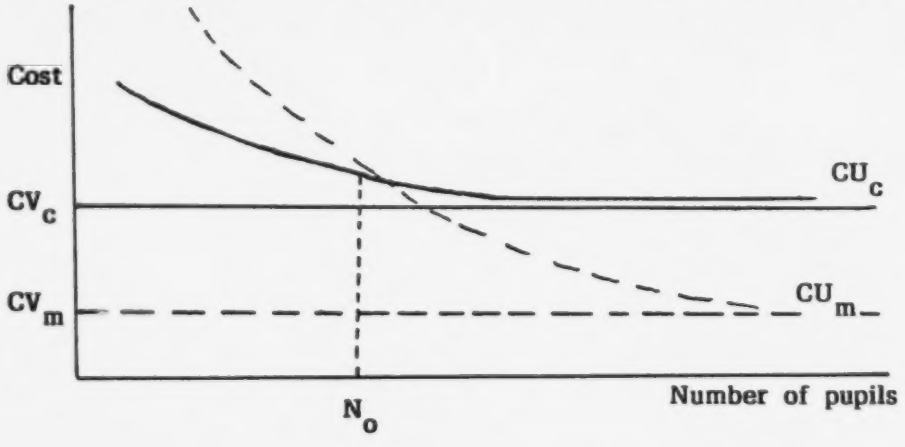
(B) Main differences in structure and evolution of costs between conventional education and a system making extensive use of NIT.

Apparently, the main difference lies in the varying extent of the fixed costs involved in the two systems. A closer analysis of the technical operations involved in ensuring the means of communication between the originator of the educational message and those for whom it intended shows that as many differences exist between the various methods of using NIT as the two types of system.

Influence of the extensive use of technology on the distribution of fixed and variable costs

Let us remember that the conventional education system requires very little technical equipment, since the teacher is always the principal means of production. As a result, the fixed costs are relatively insignifiant, especially when the whole system is taken into accoount. The cost of buildings and basic equipment (desks, chairs, blackboards, other teaching material, electrical and heating installations, etc...) is more or less fixed for any teaching establishment, whatever the number of pupils attending (4). But it varies in accordance with the number of installations, more particularly, if there are standards of size applied to the system as a whole, since very time the number of students increases by a certain figure, new classrooms or new establishments have to be constructed.

When technical equipment is used on a massive scale, on the other hand, provision has to be made for heavy initial investment. If the technical equipment replaces - wholly or partially - the teachers, not only the absolute level, but also the relevant proportion of the fixed cost, goes up. Consequently, it must be expected that initially the cost per pupil in such a system would be relatively higher, but also that is would decreases sharply as the enrolments went up. This is illustrated in the following graph :



Source : E. Mc Anany, JB Oliveira, F. Orivel and J. Stone
Distance Education : Evaluating New Approaches in Education For Developping Countries
Evaluation in Education, 1983, Vol. 6 p. 325.

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(4) Only approximately, because it is normally possible to take on a few more students in any class, for example by buying more desks and chairs.

Supposing that the variable cost per pupil is constant and appreciably higher in the conventional system (CV_c) as compared to the "modernized" system (CV_m), the total unit cost will evolve in each case as indicated in the graph. The figure CU_m, initially higher than CU_c, intersects it at a point corresponding to the number of pupils N_o. It can therefore be concluded that when the number of pupils is less than N_o the conventional teaching system is less expensive, while from that point on, the situation is reversed. Therefore, it may be observed that a system using modern teaching equipment is not economical unless and until the enrolment is relatively high. This is the only way to derive benefit from the economies of scale in relation to this kind of organization.
It is also clear that it is much more important in such a case to have recourse to the procedure of paying off the investment costs in annual instalments, so that they are distributed over the whole period during which the equipment is used. This point will be discussed further on.
The use of new technologies always brings into play more or less clearly the means of communication between the teacher and the pupil. It is accordingly necessary to break down the cost from a technical point of view, in accrdance with the successive stages of the communication operation involved.

Consequences of making use of the media

In conventional education, the message passes directly from the teacher to the pupils in front of him. Conversely, teaching through information media involves a series of technical operations for the message to reach those for whom it is intended. The cost of each of these operations varies according to the technical solution chosen.
In a technical cost analysis of the new teaching methods, education through information media is normally broken down into four stages :

- The development of the message. This phase corresponds to the preparation of the content of the subject to be taught. It arises no matter what teaching method is used, but it takes up more time in an information media system, since the potentialities and the limitations of the medium need to be taken into account from the outset. This stage is also usually more costly, for advantage is taken of it to call on the best specialist or specialists in the fiels, whereas in conventional teaching this preparation is a normal part of each teacher's work.

- The production of the message. This stage corresponds to "translation" of the message into a form comprehensible to the machine that will make use of it.

- Transmission or distribution. This stage involves the transportation of the message from the point in space where it has been produced to the place where it is required.

- The reception stage. This amounts to "decoding" of the message by the appropriate machine, so that is may be understood by pupils (5).

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(5) This points have been discussed at length in Volumes I and III of series entitled "The economics of new educational media". Vol. I, 1977 - Vol. III, 1982.

The costs involved in the first three stages of the operation are considered as fixed costs and those of the last stage variable costs, which however increase in a irregular fashion with the number of students. This analysis is in fact less appreciable to the NIT than to the audio-visual media for which it was originally carried out.
The development and production of the message involve a high fixed cost only when a selected team prepares a "course" which can subsequently be used for a large number of classes.
The cost of this operation is high for two reasons :

First, a course based on information technology takes much longer to prepare than a conventional one. This is because attention must be given to the potential advantages and disadvantages of the medium, of wich nobody can be certain at the outset. This is still more true of a multi-media micro-computer based system than of radio or television.

Secondly, for the message to be as effective as possible, it is desirable that the team chosen should include the best specialists in a wide range of fields, including the discipline concerned teaching, communication, graphics, and even marketing. These specialists are hard to find and still more difficult to bring together for the purpose of preparing good courseware. The cost in time and money is very high. The evaluation recently made in the United States and France range from $ 150.000 to two million dollars for a six-months course. But the confusion for the time bring concerns what exactly is meant by the cost of educational software.

First, it must be determined whether it involves applications software or an open programme of the author-language type. In the first case, a recent evaluation made in France (6) puts the cost at between one and two hundred thousand dollars, whereas the figures given for the other case amounted to several million French francs, that is to say ten to fifty times more.
Secondly, it is imperative to determine the number of hours of teaching that can be given by means of this software (7).

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(6) Paper presented of the European Communities' Conference on the development of educational software (25-28 May 1986), Twente University of Technology, Netherlands.

(7) The expression "by means of" shows that it would be a mistake to base the calculation on the number of hours the sofware is used. Half an hour's work with the computer could indeed be followed up by one or two hours of written work. It is always preceded and/or followed by comments and explanations by the teacher, at least in the case of use of NIT in the conventional school system. It is the same, moreover, with a textbook, which can be need in as little as twenty hours, but is used as basis for a whole teaching course.

In the evaluations I have put foward in the preceding paragraph, I attempted to convert the available figures into the cost of a six-months course, but it is often impossible to make this calculation from the available figres.

However, this information is essential, since the software is to a large extent a substitute for the textbooks and exercise books. It is by comparison with the price of the latter, therefore, that an evaluation of the cost must be made. A study recently carried out in the Netherlands (8), attempting to make such comparisons, shows how difficult the exercise is.

The author begins by pointing out that it is not enough to compare the number of bytes on a floppy disk with the number of letters used in a textbook, for it is in fact necessary to have some idea of the time spent by the pupil with each type of teaching aid and better still, if possible, of the efficiency or the (comparative) quality of the cognitive processes. Assuming the hypothesis that courseware comprising a number of signs equivalent to 100 "pages", that is to say 100 "screen-loads", provides the same "service" as a textbook of 160 pages, he differentiates the selling price of such courseware from the cost of its development, which is only a part thereof.

He considers that at present 20 hours of work are required to prepare courseware for one hour of classroom instruction and that ten hours' utilisation thereof must be envisaged for a year-long course. Since one hour of preparatory work costs about 70 guilders, the cost of a year's course is evaluated at 20 = 14,000 guilders. According to the author, this represents two thirds of the total cost involved if only one version is put on the market. It is likely, however, that the variety of the computers used and their non-compatibility call for at least five versions of any course material, increasing the cost of production by 38 per cent and reduicing the proportion of preparation cost of the software in relation to the total to just under 50 per cent. The author finds that such courseware is hundred times more expensive than a book, but it can be used by many more pupils, probably over a longer period of time, and it may well be that the cost per pupil of the two solutions works out to approximately the same amount (van D , p. 4).

The author remarks are limited to a situation within a simple establishment. If the same programme can be used in many different places, it is clear that the cost per pupil, prohibitive, when applied to a small group, will become much less, even negligible, a considerable component being the fixed cost incurred once and for all.

But the ordering of original courseware from a group of experts and its sale by a publishes is an extreme case. In practice, it transposes that much courseware design - usually in very limited quantities - is done by teachers themselves. In this other extreme case, the budgetary cost for the pupils of the teacher concerned is nil, and perhaps for other pupils if the teacher allows his colleagues to use the programme free of cost.

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(8) Kluwer International Group Educational Publishers, Culemborg, Netherlands, paper communicated at the European Communities' Conference on development of educational software (25-28 May 1986), Twente University of Technology, Netherlands.

The solution consisting in ordering considerable original courseware, that is to say in covering the whole curriculum of a subject but having the public authorities assume the fixed cost, leaves only the variable cost to be met, but it is by no means inignificant.
This wide variety of possible situation did not exist with the old media, as the cost of radio or television broadcasts is always relatively high (9).

Transmission or distribution from the place of production to place of reception can take on a variety of forms. The assumption that this operation involved mainly fixed costs was besed on the hypthesis of everything being transmitted over the air. Such dissimination in fact presupposes large-scale investments - transmitters, serials, retransmitters... - which do not vary much in volume with the number of persons to be reached. But even radio or televised messages could be recorded on cassettes and mailed at a low cost varying with the number of recipients, when it comes to software and courseware, it can also be transmitted by telephone, in the case way as computerized data. In this case, the cost of transmission is generally high and variable in terms of transmission time. It also depends on institutional arrangements, or rather that is the case with the sharing of costs between the different subscribers, since the public authorities may subsidize this kind of transmission (10).
When NIT is used in a closed circuit, for example, when a teacher uses his own courseware in his class, the cost of transmission is reduced to the cost of the energy consumed, that is to say almost nothing.
The cost of reception is more predictable and variable in terms of the audience. One receiver - a radio set, television set, micro-computer or video screen - will be required for almost every pupil or at least for each class. The cost is therefore variable in terms of the teaching method used and, often even, each particular class.
In conclusion, it may be said that the use of NIT involves relatively high costs. But it is inaccurate to say, as many often do, that these are for the most part fixed costs. As a matter of fact, it all depends on the use made of the NIT and the technical solution selected. It obvious that the cost per pupil will vary according to the medium used (television, for example, costs much more than radio), and its structure. If it comes to that, certain technologies entail only variable costs. For example, a network of micro-computers can be used in closed circuit in the classroom, with a programme designed by the teacher himself or by the pupils. In the same way, the cost of an interactive cable-based system applies only to the length of time for which it is used. It nevertheless essential to carry out of a cost analysis of the different stages of the technical process of NIT programming which can alone give an overail view of the costs and their variation patterns and enable a rational choice to be made between different possible alternatives in terms of their cost and the desired objectives.

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(9) I am oviously excluding any non-creative use, such as recording or video-recording of a conventional course and enabling other students to take advantage of it from another room.

(10) This question of cost distribution between several contributors is often overlooked, and it results in an under-estimation of the cost for the community. In the same way, when educational broadcasts are made free of charge outside normal broadcasting hours, it is often said that there are no transmission costs whereas the community in fact pays a charge amounting to a fraction of the equipment, corresponding to the amount of time for which it was used.

However, the available financial data may will be inappropriate to such calculations.

Problems posed by the type of financial data available.

In most countries, education is financed mainly from public sources. The data available therefore come from budget and have not been prepared from an economist's viewpoint. The introduction of NIT on a massive scale, moreover, may change not only the organization of educational content, but also its financing. If care is not taken, this may falsify comparisons with the conventional system. Finally, the costs of certain equipment change very nickly, and this makes any forecasts more difficult.
For the purposes of making a cost analysis, budgetary data give vise to inadequacies and problems.
Let me recapitulate briefly a few of the general problems that have become familiar (11), concentrating particularly on NIT :

- The available budgetary data are generally taken from approved budget estimates. These are accordingly forecasts and not sums actually expended.

- Budgets record only cases of reabilitation of which intists cash flows. All opportunity costs in the narrow sense of the term, that is to say, the costs involved in abandoning projects, are therefore excluded.

- Budgetary categories do not correspond to cost analysis categories.

It is especially important not to confuse capital expenditure and fixed costs, operating expenses and variable costs. The criteria used in the budget for distinguishing between capital expenditure and operating costs are purely arbitary, in as much as they are financial. If an item of expenditure is above a certain sum, it is entered in the capital budget, otherwise under operating costs. While it is clear that most of the fixed costs correspond to the capital budget (construction costs, for example), the corelation is not well defined. Besides, from the economic analysis point of view, expenditure on salary can be considered a semi-fixed cost in situations of staff reduction, to the extend that the personnal have a status protecting them from dissiminal.

- Public expenditure on education can be distributed among the budgets of several ministries and/or major public services. Since many of these ministries or services are not primarily concerned with education, their expenditure in this field is sometimes hard to identify.
In the area that interest us directly, let me note the exampkle of the "Computers for All ("Informatique pour tous") plan adopted in France in 1985. Two thirds of the expenditure on the purchase of micro-computers was financed by the Minestry of Posts and Telecommunications, and one third from the Industrial Modernization Fund in the form of a leasing arrangement.

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(11) These problems were studied in depht by J.C. Eicher in "Educational Costing and Financing in Developing Countries", World Bank Staff Working Paper N° 655, Washington, 1984.

- Central or provincial governments often grant subsidies to the local authorities. These subsidies run the risk of not being accounted for, when they are not earmarked for a particular purpose, or of being included twice in the account, since they appear in the budgets of two organizations.

In any case, the budgetary data do not cover the whole cost of education. Obviously, they have omitted all the expenditure financed from private sources, especially by the students and/or their families and by commercial entreprises.

The mode of financing a system massively using NIT can be quite different from that of conventional education systems.
Many examples show that the equipment is often partly financed by the students and/or their families or by the manufacturers themselves. In distance teaching, of the teachers (generally paid by the State) can be very low or nil, while the trainees often take these courses in their sapare time. This obviates any loss in potential comings production for the community, but involves costs for the individual.
I shall return later on to this point, but it seems important at this point to note that the changes in the source of funds can completely distort any comparison between the two teaching systems, if seen in the light of budgetary data alone.
Lastly, the costs and the technical characteristics of most of the equipment in multi-media systems using NIT are changing rapidly.
Historical data therefore do not constitute a satisfactory basis for assessing the cost of any future project. The extrapolations resorted to by certain authors could turn out to be erroneous, as I shall point out in the second part of this report. Let us now try to answer this question as to how the introduction of NIT affects the cost of education, by first placing ourselves in the context of the system with which we are well acquainted.

II. Effects of an extensive introduction of NIT on the costs of conventional education

The introduction of considerable technical media into conventional education cannot but entail, some significant changes in the organization and even the content of teaching, provided this technology is efficiently used. The introduction of audio-visual methods was an experience from which many conclusions can be drawn. It may be observed that each time this equipment was used only for marginal enhancement of normal classroom work, usefulness proved to be insignificant and its utilization irregular and often short-lined. It is none the less true that there exist everywhere institutionalized education systems characterized by a high degree of rigidity. They cannot be replaced by a totally different system overnight, even with the conviction that the new one will be more cost-effective. It must therefore be assumed that the introduction of NIT into conventional education will not, in the short term, cause major disturbances in its organization or content. There is a price to be paid for these technologies, and their installation and operation will necessarily involve other direct and indirect costs.

(A) Cost of equipment : problems and prospects

The very optimistic evaluations that have appeared in the last few years pertained only to the micro-computers themselves, without including even their peripherals. Yet, for the NIT to function efficiently, they must be set up as multi-media systems including various devices. Moreover, micro-computers function efficiently only when provided with high-performance software.

The cost price of micro-computers has gone down dramatically since their first appearance on the market about ten years ago. But can past trends be extrapolited directly, and are they correctly interpreted ? On the other hand, the development of micro-computer technology has taken place outside the shcool and not been based on its particular needs. It is possible to contemplate, and at what cost, the development of a micro-computer specially constructed to meet the needs of education ?

Basing their findings on the evolution observed since the begining of the 1980, some authors have not hesitate to predict that, from 1990, micro-computers, sufficiently adapted to meet the needs of education, will become available on the market at a cost of a hundred dollars. More reasonable economists, not confusing production cost and sales price, have put the cost at around three hundred dollars and expressed the view that there was not doubt more to come (12). These assesments have several difects which make them unreliable :

- The extrapolations are based on the assumption that a dramatic fall in the cost of micro computers of a given capacity (-50 per cent every two years since 1980) will still continue for a number of years. However, the different parts that make up a micro-computer shows that only the cost of printed circuits has gone down dramatically. At present, these no longer represent a major part of the total cost, and there is no reason to expect a sharp future drop in the price of the other components, both because a major part of their cost is accounted for the salaries of the workers who manufacture them, and because there is no major break-through in sight in the foreseeable future.

- The machines available are becoming more and more efficient but it is usually not possible to go on buying the earlies models at a lower price than before. There is therefore an increasing tendancy to replace inefficient machines by more powerful and "intelligent" ones at much the same price.

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(12) The first of these evaluations was made by Ray Reddy, the second by Jacob Schartz. For more detailed discussion and references, see my report to OECD already noted, pp. 19 to 25.

- In general these evaluations concern the United States.
As most of the developed countries have subsidized their national computer industries and have imposed locally produced material on their educational institutions, it is quite likely that the price of micro-computers in these countries will remain higher than in the United Stated, on account of the limited volume of production. Accordingly, one is rather led to expect that present prices will not fall appreciably. It must however be pointed out that development in computer science in general, and particularly in micro-computers, has been tailored to meet needs of the economy, that is to say, the education system. While it is true that these machines can be used for teaching, do fact nevertheless remains that the existing equipment, designed for other purpose, is at best only partially adapted for use in scools. The development of machines specially designed for teaching would be extremly costly, and the number of units required would be too small to provide low costs achievable through volume production. It can thus be deduse that if a decision were made to design such specialized computers, it would result in an increase in present prices per unit and not a decrease.

The cost of other hardware is not likely to decrease appreciably. For the NIT to operate at full efficiency, micro-computers need to be backed up by a series of other technical instruments, either to allow access to data banks or for recording and reproduction of images, for tracing complex graphs or for communication with other micro-computers. Technologies that have not developed as rapidly as computer technology in the recent past are required for the manufacture of most of this equipment, and they are not expected to make any major breakthrough in the immediate future. These instruments often cost more than the micro-computer itself, which strengthens the assumption that the future decrease in the cost of computer hardware will be much less than anticipated. Software is required to make these integrated systems work.

Existing software is expensive and inefficient. This is particularly true of courseware, the preparation of which, as we have seenn, demands the consideration of special skills and is accordingly very costly. It is also true of other types of software (word-processing, scientific computing, etc...) although considerable progress has recently been made in the quality of these types of software. We can expect the quality of existing courseware to improve in the future, but its cost is not expected to fall very rapidly nor very significantly.
Indeed, there are several factors that militate against such a decrease :

- First, as I have pointed out above, the production of high-quality courseware requires the services of specialists who are few in number. They therefore have a sort of monopoly, so that their fees are very high.

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- Secondly, the selling price per unit depends on the extent of the market, because of the high fixed costs. This market is at present very limited, casing publishers to be reticent about going into this field, thus limiting competition and helping prices remain at their crrent high level. Te study carried out by Van Dalen, quoted earlir, reveals for instance that at least 400 copies of a single programme to be sold for the publisher to break even, which is much too high given the wide variety of computers in use.

- Thirdly, the cost of maintaining software, still not will defined, is considered by some as far fromm negligible.

It is of course possible to ask teachers to design their own courseware or to encourage some of them to specialize in this field. In this way some courseware at affordable prices could be obtained but these would be only bits and pieces, frequently mediocre in quality.
The unit cost of all te equipment required for teaching based on NIT should therefore go down in the future, but much less than some have led us to believe. Nevertheless, the cost per pupil may very well prove relatively low. This is obvious when it comes to courseware, if it can be used by hundreds of thousands or even millions of pupils.
It is also true of the hardware, but in different degrees, depending on the use to wich it is put. To demonstrate this clearly, let us take two theorical examples, using as principal variables figures that seem reasonable.

/Case N°1/ : A micro-computer is used to inculcate in pupils a minimum aptitude in logicial reasoning and in solving problems through an introduction to programming in LOGO.
The micro-computer equipment must fulfil at least the following requirements :

- Minimum working time with the machine : 15 minutes per working day, that is, 40 hours per year and per pupil (13).

- Number of pupils per machine : two.

Tis means that at least one micro-computer has to be purchased for a class of 24 pupils if we count 6 working hours per day and, with idle time, we must calculate on the basis of 30 minutes per pupil.
It is very difficult to estimate the cost of the software.

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(13) These figures are those arrived at by Papert and his associates in their report on the "Brookly Logo Project".

We shall use here the rental cost reported in the evaluation of the Los Angeles Unified School District experiment by Levin, Glass and Meister (14), even though it is somewhat different in nature. This cost was :

49,800 dollars (fixed cost).

If we take a price of 1.500 dollars per each micro-computer, along with its peripherals, we get the following result :

Annual cost of hardware : 300 dollars (payable at 10 per cent over 6 years),
i.e. $ 300 + 24 = $ 12.5 ;

Cost of software : if the system is used by 1.000 pupils,

$$\frac{49,800}{1,000} = 50 \text{ dollars approximately}$$

It is therefore clear that the cost per pupil varies between 62.5 dollars and 13 dollars depending on the size of the class, that is to say, it is never very high and becomes negligible when the number of pupils is considerable.

/Case N°2/ : A set of technical equipment (micro-computers, inter-active video-disks, high definition display screens, interfaces to gain access to data banks, etc,...) is used to enable pupils to pursue their studies in all subjects semi-autonomousl.
The equipment needed in this case is much more considerable and costly than inthe previous case. Considering that each pupil is going to use the computer for an hour a day (or that each group of two pupils will need the computer for two hours), te need can be estimated at one micro-computer for approximately five pupils (15). If the unit cost of the hardware is estimated at three times that of the previous case, which is to say 5,000 dollars per set, the annual instalmets will be of the order of 1,000 dollars, that is, 200 dollars per pupil.
The software and courseware required might also be much more expensive.
Taking a figure of 250,000 dollars (16) we get :

- for 1000 pupils 250 dollars per pupil
- for 100,000 pupils 2.5 dollars per pupil.

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(14) Levin H.M., G.V. Glass and G.R. Meister (1984) : "Cost Effectiveness of Four Educational Intervantions", Stanford University, IFG report no.84.All.

(15) This is an approximate figure. It does not take into account the fact that at least partof the peripherals can be shared by several pupils although, on the other hand, it probably underestimates the time a pupil needs to spend at the machine in a system in which he is largely atonomous, or rather the time during which a micro-computer per pupil would be needed for each of them, at any time, to have access to data-banks or video-disks.

(16) This figure is probably a minimum if account is taken of the estimated cost of six-months course quoted above.

It may be seen that for such use of the NIT, the cost per pupil could be rather high (450 dollars) if the number of pupils should be limited, and would remain fairly high (202.5 dollars) even if the number of pupils should be very considerable. These rough estimates must be treated with caution. At least theyhave the advantage of dimonstrating that there must be a dear-cut teaching project before any attempt can be made at a theoritical evaluation of the costs of a reform involving massive use of NIT. As far as we know, till now no reliable estimate has been made concerning the minimum use per pupil of the micro-computer, with the exception of the one by Papert in the case of LOGO. No consensus exists either on the way NIT should be used in schools, and there is a feeling that the public authorities (in the case of centralized systems) or educational establishments install NIT equipment without having in mind any specific educational objective, so that it is impossible to make any reliable evaluation.

(B) Operating cost of the hardware

These costs are generally underestimated because they are not taken into account fully or, in some cases, completely overlooked in the estimates available. Nevertheless, a logical analysis has enables us to identify several categories, and the example of a reliable evaluation shows that they are quite high.

The different elements that make up the operation cost can be identified by careful observation of practical situations. They can be classified in five categories :

- Costs directly linked to the hardware : maintenance and repairs. They are quite high for two reasons. The manufacturers have no interest in making equipment that can easily be repaired by the user himself; in addition, an education system generally has no staff capable of carrying out day-to-day maintenance, and the manufacturers often count on rather one-sided maintenance contracts to increase their profits.

- Costs of adupting premises - requisite furniture, electrical installations, special security arrangements, sometimes construction of suitable premises.

- Cost of surveillance : it is generally necessary to take on staff to guard the premises and carry out the day-to-day maintenance.

- Operating costs : consumption of electricity, purchase of tapes, blank video-cassettes, paper for print-outs, etc...

- Finally, the cost of gaining access to data banks should be included here. Gaining access to data banks is a complex matter. Some of the problems involved are of a technical or legal nature (ownership of documents), but for the moment these banks are under-utilized because of a serious financial problem, there being no free access to such banks. The medium used for gaining access can be costly (telephone channel) and the information itself often has to be paid for. Yet a very significant extent the efficient use of these NIT may depend on the possibility of recourse to existing data banks. Precise and exhausive calculation of the operating cost do not exist to all intents and purposes. Nevertheless, it is interesting to quote as an example the most accurate evaluation made to date, that by H. Levin and his associates in the ETS/LAUSD study (1984).

This evaluation is sub-divised as follows :

- Cost of suitable adaptation of premises :

  One classroom for the laboratory for computer-assisted teaching, 5,775 dollars (including 1000 dollars for fluid and day-to-day maintenance) :

  . remodelling of premises : 3,010 dollars

  . furniture : 244 dollars

- Cost of maintenance of hardware : 9,720 dollars (3,600 dollars for the central unit, 5,760 dollars for the pupils' terminals and 360 dollars for the printer).

- Insurance : 3,000 dollars

Total : 21,749 dollars for 736 pupils, that is, 29.5 dollars per pupil.

It is interesting to compare this cost with that of the hardware, which is about 43 dollars per pupil. It amounts to more than two-thirds of the latter. Adding on the cost of teaching staff appointed or used partitions for such activities, one comes to a total of 54,500 dollars, that is, almost twice the cost of the hardware.
The importance of calculating carefully the operating costs emerges clearly. Moreover, massive introduction of NIT also affects the operating costs of "normal" teaching.

(C) Effects on "normal" operation

The partisants of NIT claim that these replace, at least partially, teaching staff, and thus help to reduce appreciably the amount of salary paid out, which is the largest part of operating costs.
On reflection, it seems that the net effect on the salary costs of teachers is much less evident than these authors are willing to admit, and that other increases are involved. A case for the introduction of NIT in schools in the developing countries needs to be considered separately, since there is clearly a tendancy to underestimate the cost-efficient use of these instruments.

As far as the industrialized countries are concerned, the effects of the introduction of NIT on **teaching costs** are both positive and negative. It is possible that the use of these machines can theoretically result in a reduction of supervisory staff and thus reduce the cost per pupil. The pupils spend part of their time with the machine without constant supervision, the teacher theoritically being in charge of only part of the class, so that he may be able to supervise larger classes just as effectively as in conventional circumstances. This technical possibility can be given more or less significance, depending on the kind of use made of NIT. It has been seen in example N°1 above that hands-on time with the machine cannot exceed fifteen minutes per day, which scarecely involves any change in supervision.

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On the other hand, the possibilities of substitution increase with the level of education, primary school pupils receiving much more constant, personalized attention than those in secondary schools, and more particularly in the case of university students. Secondly, in the short term, there are institutional obstacles to extensive lay-offs of teachers, even if it is theoretically possible. Teachers are generally protected against lay-offs, except in the event of serious misconduct, by the terms of their contracts. In such a case, thechange can only be marginal and gradual limited to the non-replacement of those who leave their job (retirement, death or resignation). The chancesof reducing the cost of teachers by reducing their number are therefore in practice very limited. On the other hand, the cost of training staff necessarily goes up when NIT are introduced.

The efficientuse of these new technical media calls for appropriate training. Initial training must accordingly be modified, with a probable increase in cost and, moreover, the need for all teachers in service to undergo retraining.

Certain countries have undertaken a vast programme in this direction, involving considerable expenditure. I have attempted a cost evaluation of this training in progress in France in 1985. The amount spent was of the order of 700 million francs, the equivalent of approximately a hundred million dollars at the current rate of exchange. This amount, which seems very considerable at first sight, represented only 3.7 % of the operating budget of the Education Ministry.

In our opinion, however, the effort made, though very large compared will anything similar undertaken elsewhere, can be regarded as far below the training required of teachers able to make efficient use of NIT (17).

It may therefore concluded that giving adequate training would involve a significant increase in staff costs. It is necessary not only to give thought to the design of teaching methods and the organization of training courses for teachers - computer initiation courses, refresher courses, the training of the computer educators - but also to the financial implications of the options taken up.

It is not the same thing financially, for example, whether these courses are organized during the academic year or during long vacations. An analysis of the solution adopted in France for introductory training courses (attended by 110,000 teachers in 1985) reveals that the decision to conduct the courses during school vacations resulted, despite the bonus paid to the teachers attending, in a saving of 50 per cent in comparison with what the cost would have been had the training courses taken place during the school year, necessaiting the replacement of teachers in the classroom. (18)

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(17) For details of the reasoning hading to these conclusions, see J.C. Eicher : "The new Technologies and the Training of Teachers in France. Report prepared for the European Institute of Education and Social Policy, 1985.

(18) This solution cannot generally be applied to courses of long duration but, in any case, a detailed study of the relevant costs of the different options available is of importance when the number of persons concerned is large.

It seems clear that those who thought that the introduction of NIT in conventional schools would appreciably lower the cost per pupil, by achieving at least a partial replacement of teachers by the technical means, were labouring under a delusion, at any rate in the case of the industrialized countries where the education system no longer increases appreciably, on account of the decrease in the birth rate and a relative saturation of the demands of the system of production. At best, these countries, in the medium term, stabilization may be expected in the cost per pupil of teachers' salaries. The introduction of NIT can also indirectly affect current operating costs (in addition to its direct effects in terms of installing hardware, described above). Indeed, it may result in school premises remaining open for longer hours. It is noteworthy that some pupils wish tobe able to use the micro-computers outside school hours and, moreover, that local authorities, who often help finance the equipment, desire that other users should have access to it, which can only be managed outside school hours, in the evening, week-ends or vacations.

This opening up of the primises for longer periods of time cannot fail to involve additional costs in electricity, caretaking and maintenance, leaving aside the remuneration of the instructors, and it is not normally provided for by the school itself.

The case of the developing countries presents various characteristics that need to be pointed out. In the countries where education is still under-developed, and especially in those where universal primary schooling is far from being achieved, the leeway open to reformers is on the whole more extensive. It is, in fact, easier to establish a new type of school in a place where none existed before than to bring about major changes in existing establishments, just as is easier to engage for new schools fewer teachers than would have required under conventional organization than to dismiss part of the existing staff.

The example of Radioprimaria in Mexico, where the last three primary school classes have been opened with one teacher instead of three, using radio broadcasts and teaching materials printed centrally, shows that such changes are possible. The cost per pupil in this case has proved to be 38 per cent lower than in conventional schools, the cognitive results being considered approximately the same.

With the use of NIT, technical and practical problems are likely to assume much greater importance, and there is a tendency to underestimate the minimum environmental requirements for the desired operational efficiency. This point has been highlighted recently by two American authors. They haveput forward the thesis that in practice the NIT have not attained their potential, because the environmental constraints were underestimated and accordingly not overcome by appropriate investment. They conclude that properly designedprojects are likely to cost appreciably more than the costs generally observed (19).

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(19) Cf. Frances Kemmerer and Alan P. Wagner : "Limits on the Use of Educational Technologies in Developing Countries : A Reappraisal of the Costs". Report to International Symposium : "L'Economie de l'Education"; "Les Nouveaux Problèmes". Dijon, 23 - 26 June 1986.

According to these authors, the cost graph implicily assumes that all other inputs are available in sufficient quantity, so as to obtain, with the introduction of the new technological equipment, the cognitive attainments expected (20). Yet the result depends on the achievement of an optimal combination of inputs, has been overestimated, this will give rise to cognitive results lowerthan expected. If the other inputs are brought down to the desired theoretical level, the costs will be much higher than anticipated. The inputs that are most frequently overestimated are :

- The professional level of the staff responsible designing media programmes and their operation. In most cases, projects using NIT are designed and set up by assistance organizations or agencies which employ, especially at the outset, expatriate staff. But, after the project gets under way, these people genrally withdraw and then it transpires that the country is unable or unwilling to replace them by staff of equal competence.

- The qualifications of the teachers who are to use these technical media in their classes. Not only their pre-service training sometimes inadequate to enable them to do more than repeat what they have learnt but, more particularly, they have usually not been given sufficient further training that would make it possible for them to exploit the capabilities of these media.

- The distribution chains for the accompanying documentation and the equipment are often very unreliable. It transpires that the documentation does not arrive in time, that the equipment is not distributed or not properly maintained, with the result that the new teaching are often unusable.

- The means of transmission for educational "messages" are sometimes of poor quality or erratic. The examples given by the authors apply to audio-visual media and it is obvious that these problems will be more acute when NIT equipment is involved.

In conclusion, it may be said that the cost-effectiveness of the NIT in the conventional education system is probably much less formable than the description of ideal circumstances might lead one to believe. As far as costs are concerned, we observe an underestimation of the direct costs of NIT and the necessary adaptations required in the teaching system, particularly in the developping countries, where the minimum conditions for effectiveness are generally lacking from the outset.
In any case, it is certain that careful analyses taking account of all the factors enumerated above need to be carried out as a matter of urgency. At first sight, the prospects seem more favourable in respect of out-of-school training.

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(20) Ibid, p.5

III. Probable cost implications for use of NIT in out-of-school contexts

The NIT can provide that the teaching systems with which we are familiar are unable to provide or provide unadequately. Somme of these services are generally rather more expensive that the costs of conventional education.This is particularly the case with the first courses hading to an official diploma or reconized educational qualifications, available to groups which, for various reasons, are unable to attend school : severely handicapped persons, children of immigrants, children living in very thinly populated and/or inaccessible areas, children of nomads, etc...
The cost of this education can be high, as these children require close supervision and because the fixed costs cannot be spread over a very large number of participants. But this cost is high only in comparison with conventional education, which is not available to these persons.
The comparison is therefore not relivant, and it is more than likely that distance teaching is the best possible solution, at least for some of these groups. However, we are more interested here in types of training which, in comparison with the conventional system, are at one and the same time more effective and less expensive.
In addition to the groups mentioned above, there are three categories of individuals, increasing in numbers, whose needs the schools will find it very difficult to fulfil :

young people who have left school without any training at all; working people who wish to improve or modify their professional qualifications; and non-working adults, often those already in retirement, anxious to supplement their educational and/or cultural attainments.
It is not by no means sure that an extensive use of NIT, in itself, can solve the problems of the first group (21) or in any case, that it can do so at a cost lower than that of conventional education, since only qualified human supervision can help such young people to overcome the psychological problems which turn them into social misfits as well as unskilled workers.
On the other hand, a series of logical or empirical arguments can be put forward to show that, subject to various conditions, it is possible to reduce very substancially the cost of training for the two other groups in comparison with the costs of conventional education.
It is also possible that this new method of teaching may loud itself to some modifications in the financing of education, especially when the greater part of the financial burden is borne by the State.

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(21) It can nevertheless make a contribution, if we are to believe the findings which indicate that the possibility of using micro-computers has more or less reconciled to schooling young people who had rejected it, as it had rejected them.

(A) Factors of reduction in cost and their limitations

Distances teaching using NIT can help bring down the cost of teachers and buildings and reduce loss of income. Subject to certains conditions and within certain limits, the cost per student of the new equipment and utilization can be minimized.

The cost of teachers, in relation to that in conventional schools, can be brought down only if they can be replaced by technical media. It would be unreasonable to imagine that recourse might be had to personnal less well paid and consequently less well qualified.
Such replacement is theoretically possible, since teaching can received individually or in small groups. It is also possible in practice, at least for students belonging to the last two groups mentionned above. These adults do not in fact need supervision in order to learn as they are generally motivated and autonomous enough to make use of the receiving equipment by themselves.
In most cases, however, these possibilities have their limitations.
First, they would be much more restricted if it were desired to replace conventional primary school lessons by distance teaching, and even if this were begun at the level of students who are already relatively autonomous adolescents, that is to say, in higher secondary education or at the university.
Secondly, even classes composed of adults require a minimum of human contact with those who have prepared the courseware or with teachers having a good grasp of the subject. This is specially true of courses leading to qalifications, where the students find it important to know where they stand in relation tothe standard required in the examination and as regards other students. It also applies to courses with more cultural content, where students need to have discussions with their teachers. It is nevertheless possible to reduce the teaching staff considerably in many cases, and this can result in substential savings.

The cost of premises should also be very low in most cases since to a large extent, the teaching is extra-mural, because the students are not grouped together in one place.
In actual fact, the students need to be brought together from time to time, even if it does not happen daily or indeed very often, for the reasons stated above. It is reasonable to expect that in many cases use can be made of existing premises, more particularly because they are required only rarely and can be usedoutside normal hours as the students are either free to dispose of their time - unemployed or retired people - or not in a position to obtain paid leave from their employer.
Therefore, school buildings could be made available for such gatherings either in the evening, during week-ends or during school vacations.
Loss of particular comings is often the major component of educational costs to be borne by those involved (22).

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(22) This is obviously true only beyong the age of compulsory schooling in the industrialized countries, where employement of children who have not reached this agois forbidden by law.

Distance teaching can help overcome, or at least reduce appreciably, this part of the cost, provided it is organized in a flexible manner enabling working students to follow the courses outside their working hours. This does not mean that sacrificing lessure is not a cost in itself. But it can safely be assumed that in most cases this cost is less than loss of income, as the students concerned wish to benefit from the training and can derive immediate satisfaction from it.
Obviously, in the case of those not actively umployed, the question of potential loss of income does not normally arise.

The cost of NIT equipment and its utilisation is very high. As we have seen, however, in the first part of this report, its cost per pupil can be relatively low if certain conditions are fulfilled. The best way to reduce the cost per pupil is to increase the number of persons using the same set of equipment, so that the fixed costs incurred can be distributed over a larger number of individuals. But, as has been made clear, the extent of the fixed costs depends upon the kind of organization and the use made of the NIT.
In the case of distance teaching, it is clear that courseware has to be used, and it can be designed by a single team. Generally the savings of mass production in such cases are substancial. However, the demand from two main groups of people - the working people wanting to acquire additional qualifications and adult unemployed - is characteristically individual. Each person has his particular needs, and these needs never completely coincide with those of others, or at least with those of the majority. This would seem to rule out the possibility of the same coursewarebeing used for a large number of students. As a matter of fact, even when the demands are varied, they are generally related to the same subjects or to the same fields of study. It is usually possible to divide up the courseware into different sections, each person chosing the sections that interest him.
If the coursewareis distributed to individuals and not to institutions, however, it is likely that their price will tend to be the same as the market price, that is to say, much higher - especially if there is little competition - than if the Edcation Ministry of the country concerned bought up the whole output and made it available to institutions functioning under its direction.
Generally speaking, the cost of distance teaching can be much lower than the cost of conventional education. But the difference may vary greatly, depending on the soluton adopted by the institutions concerned and on the technical organization of the system.
Here again, the evaluations made should follow the cost analysis categories mentioned in this report and compare various possible solutions before getting a project under way, and then compare the results obtained with the forecasts, in order to draw the appropriate conclusions. It is also important to clarify the sources of financing, as they may be quite different from those observed in conventional education.

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(B) Effects of the introduction of NIT on Financing

In existing school systems, the salaries of teaching staff are generally financed by the public authorities, whereas the other expenditure (current operation, school supplies, construction and equipment) involves participation - more or less considerable, depending on the country - by the pupils and /or their families.

The fact that expenditure on the salaries of teachers should unusually be going down quite sharply leads me to predict that this technical change will bring about a new distribution of costs between public and private sources, with the share of the latter in the total rising appreciably.

As regards the cost of materials, both logical reasoning and empirical observation tend to show that the whole or part of the cost is borne by the students themselves. This will prove all the more true when those using the system are isolated from one another, which is generally the case with adults who are looking for additional qualifications or broader cultural background.

Financing by the manufacturers and/or the local authorities is also likely to increase in relation to the situation in conventional education.

The manufacturers may be encouraged to sell their products at a lower price for the publicity it gives them. They do this more readily when educational institutions are involved, in the hope that it will result in an increase in purchases made by families.

The local authorities are under pressure from social demand, and elected officials are inclined to satisfy their electors, especially when these people are very close to them, living in the same community.

This shift in financing from the State to other contributors should take places in the same way. Although on a smaller scale, in the case of conventional education. The introduction of NIT is thus means of solving, at least in part, the budgetary difficulties that the public authorities responsible for education encounter in almost all countries.

CONCLUSION

This study has not been able to give precise and up-to-date information on the costs of the NIT and their development. That is not surprising in the light of what I have attempted to analyse. What I have actually tried to show was that it is difficult to analyse the costs of NIT because of differing technical solutions and of their differing impact of the cost of the education system, and also because of the rapid evolution of prices and the quality of various hardware. Such an analysis is indispensable, not only for the purpose of updating our information, but also to act as a guide in making a choice between the alternatives available, without overlooking the fact that, after all, the analysis and quantification of costs, in themselves, are without interest. Only a simultaneous analysis of costs end benefits (or more genrally of the advantages) serve as a guide.